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A NOVEL APPROACH TO THE GENERATION OF MULTIPLE GRAVITY ASSIST TRAJECTORIES

Abstract

A complete interplanetary trajectory can be thought of as a restricted four-body problem involving departure and target bodies, Sun and spacecraft. It is possible to run N-body simulations to design the trajectory, but the number of variables and the computing time makes this approach practically useless. The patched conics technique is the most widely used approximation for the preliminary design of interplanetary trajectories. It relies on the assumption that the dominant attractor switches between planet and Sun at the crossing of some boundary surface, thus introducing a model discontinuity: the interplanetary path is determined by the Sun only, and two-body analytic relations (e.g., Lambert's problem) define the path from departure to target body, given a set of encounter dates. However, the problem gains several degrees of freedom and becomes hard to solve if the foreseen number of gravitational encounters is large. Furthermore, the patched conics method lacks the possibility of automatically identifying the swing-by parameters required to reach the target body for the following encounter or the final rendezvous. The proposed approach takes the steps from the physics of the gravity assist, i.e., the dependence of its dynamical effects from any two parameters defining the planetocentric hyperbola, the time of pericenter passage and the angle formed by the line of apsides with the heliocentric velocity of the planet. All the trajectories that are obtained by combining these parameters for the departure planet are propagated in heliocentric frame. Some of them will cross the sphere of influence of the first encounter planet. Allowing for a discontinuity in velocity at the pericenter of the hyperbola, increases the number of solutions to be propagated in search for the following target. The procedure is iterated over the foreseen number of encounters. The approach adds nothing new to the patched conics model, but offers considerable advantages, among which computing time reduction and completeness. As a matter of fact, all the trajectories with powered gravity assists for a given encounter sequence appear in the output of the search. Furthermore, the method gives a clear account of the geometrical parameters of the swing-bys. As a result, pruning the solution space (e.g., too large pericenter distances, Sun escape hyperbolas, too low perihelia) can be done in a natural and intuitive way. The method lends itself to the application of optimization algorithms and, exactly like the traditional approach, can be refined to a perturbation model.